# Seasonal variations of $CH_4$ emissions in the Yangtze River Delta region of China are driven by agricultural activities

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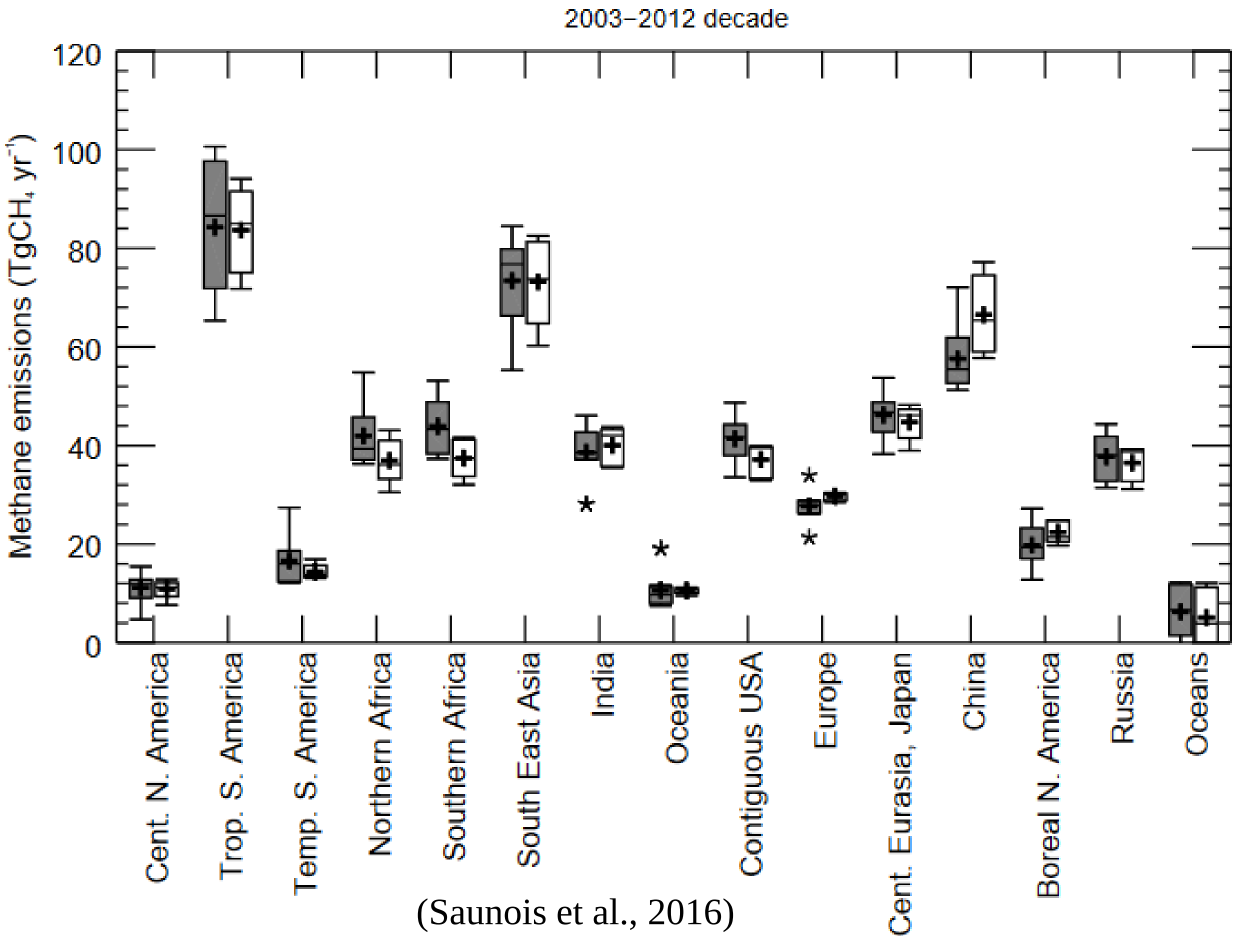
# THE MAIN CONTENTS

# 1

# Background

# 1 Background

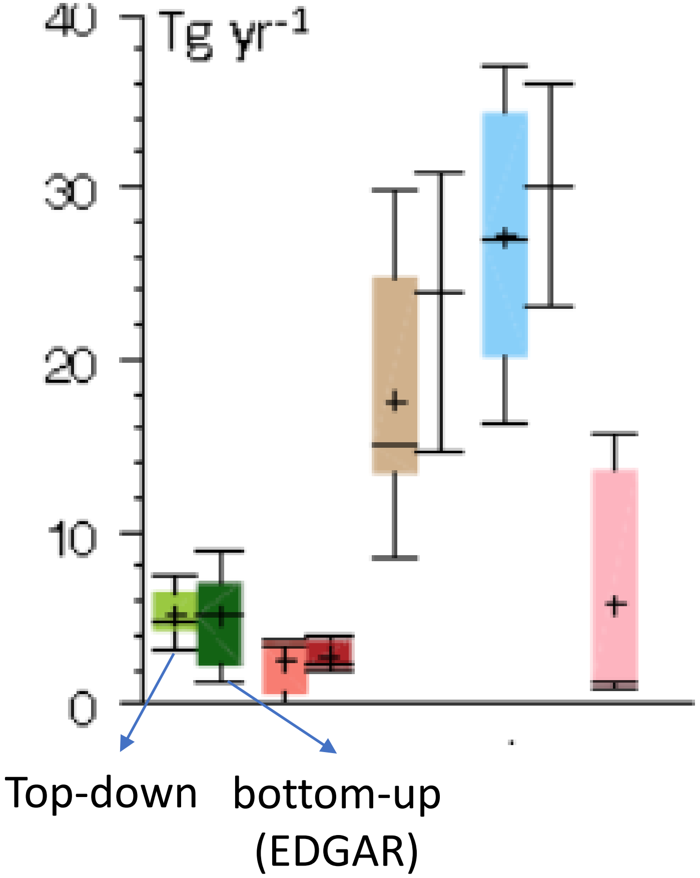
- ✓ Increasing of $CH_4$ emissions
- ✓ Neglect of natural sources
- ✓ Overestimation of anthropogenic $CH_4$ emissions in EDGAR




(Saunois et al., 2016)

# 1 Background

2003-2012




Wetlands

Biomass burning

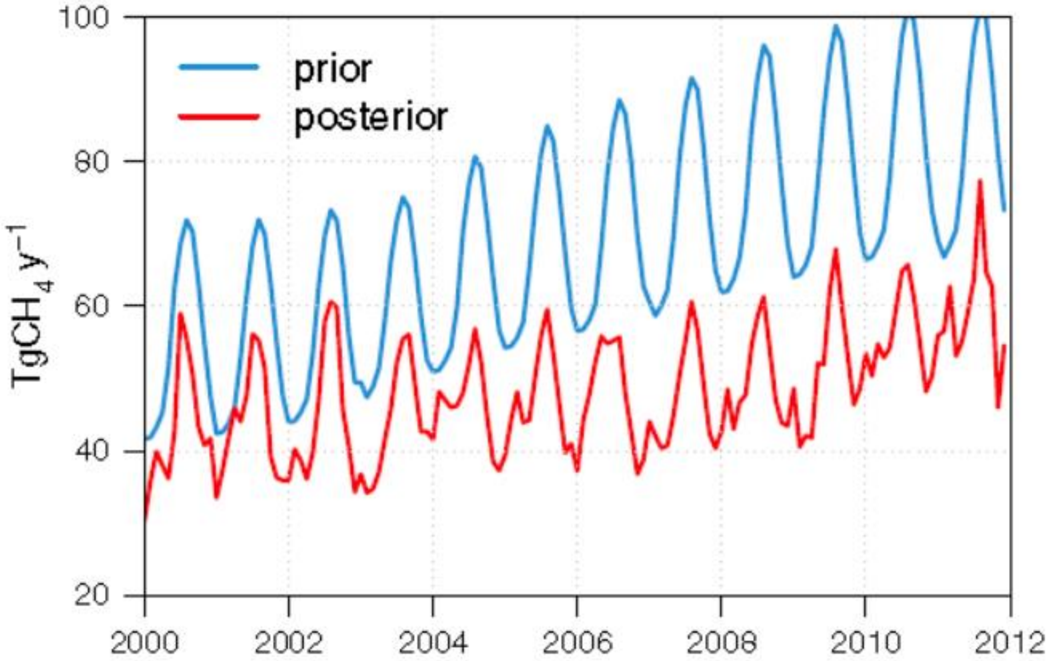
Fossil fuels (√)

Agriculture and waste

Other natural

(Saunois et al., 2016)

East Asia




“The greatest difference in emissions, a posteriori with respect to a priori, was found in eastern China, especially in regions important for rice agriculture and, in particular, in the summer months.”

(Thompson et al. 2015)

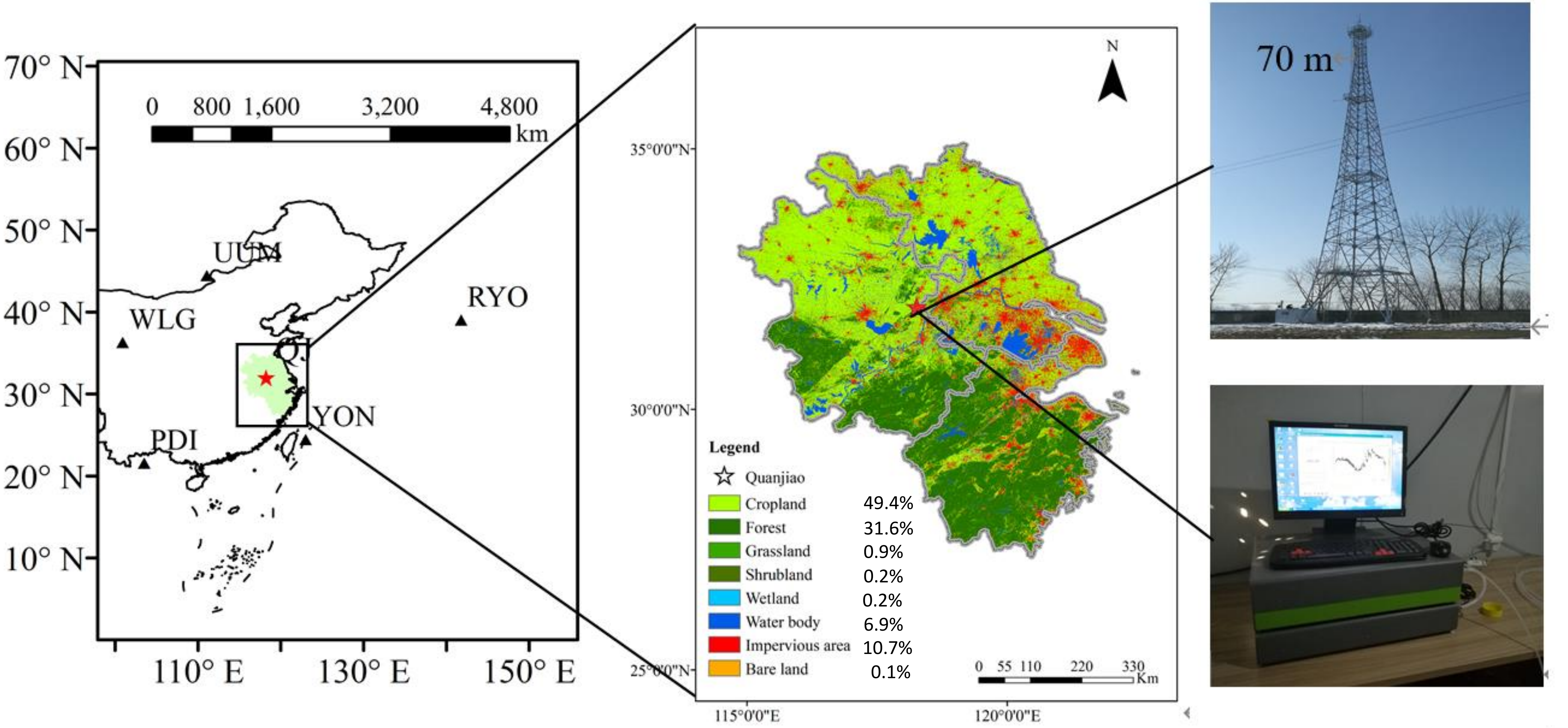
## Main objectives

- Constrain the major $CH_4$ sources within the Yangtze River Delta (YRD) region at seasonal timescales and identify the main sources that control the seasonality of $CH_4$ emissions;
- Assess the relative importance of natural $CH_4$ emissions from wetlands and water bodies in the YRD region;
- Evaluate if there are important biases in the *a priori* $CH_4$ emissions associated with bottom-up inventories (EDGAR);
- Estimate the total anthropogenic and natural emissions of $CH_4$ for the YRD region.

# 2

# Material & method

## 2 Material & method




Five WMO/GAW stations：

(1) Ulaan Uul Mongolia (UUM) (2) Waliguang (WLG)

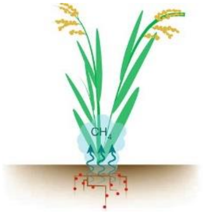
(3) Pha Din (PDI) (4) Yonagunijima (YON)

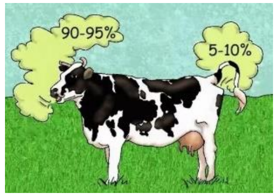
(5) Ryori (RYO)

30 m × 30 m

(Gong et al., 2019)

Anthropogenic sources

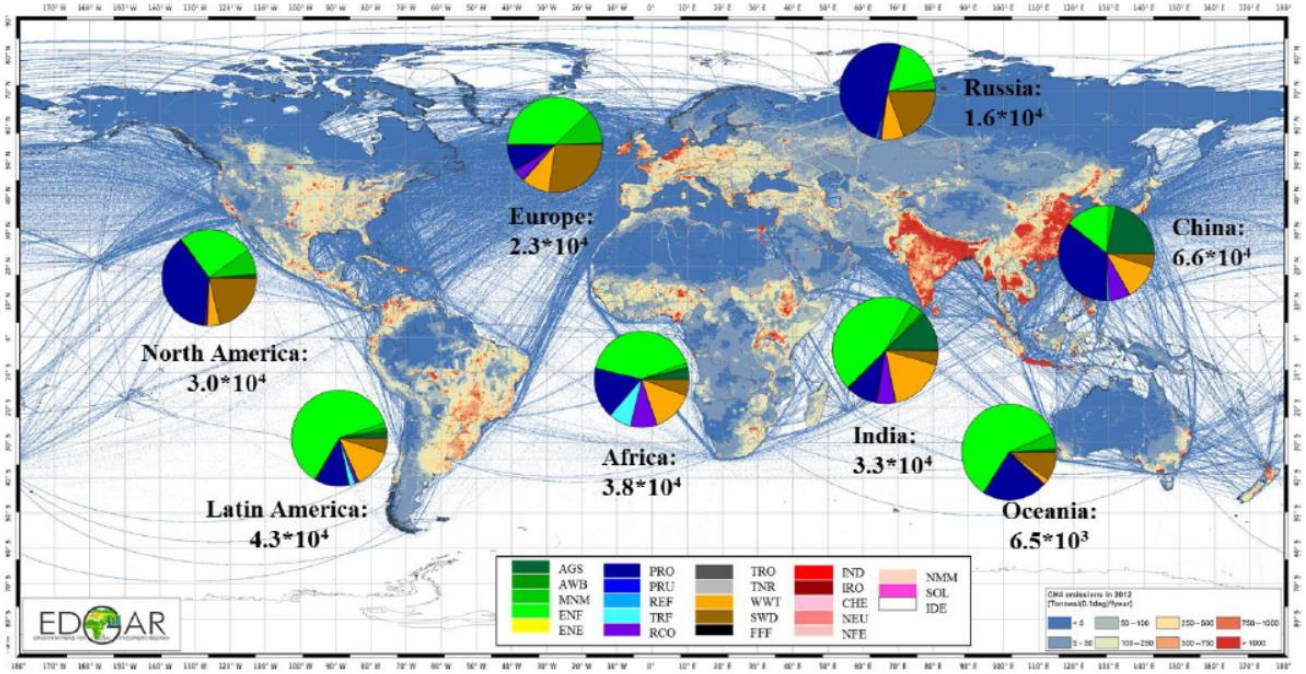




…

EDGAR v432
0.1° × 0.1°
2012

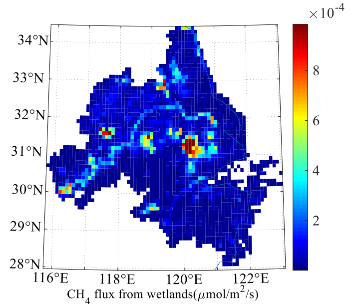



(Janssens-Maenhout et al., 2019)

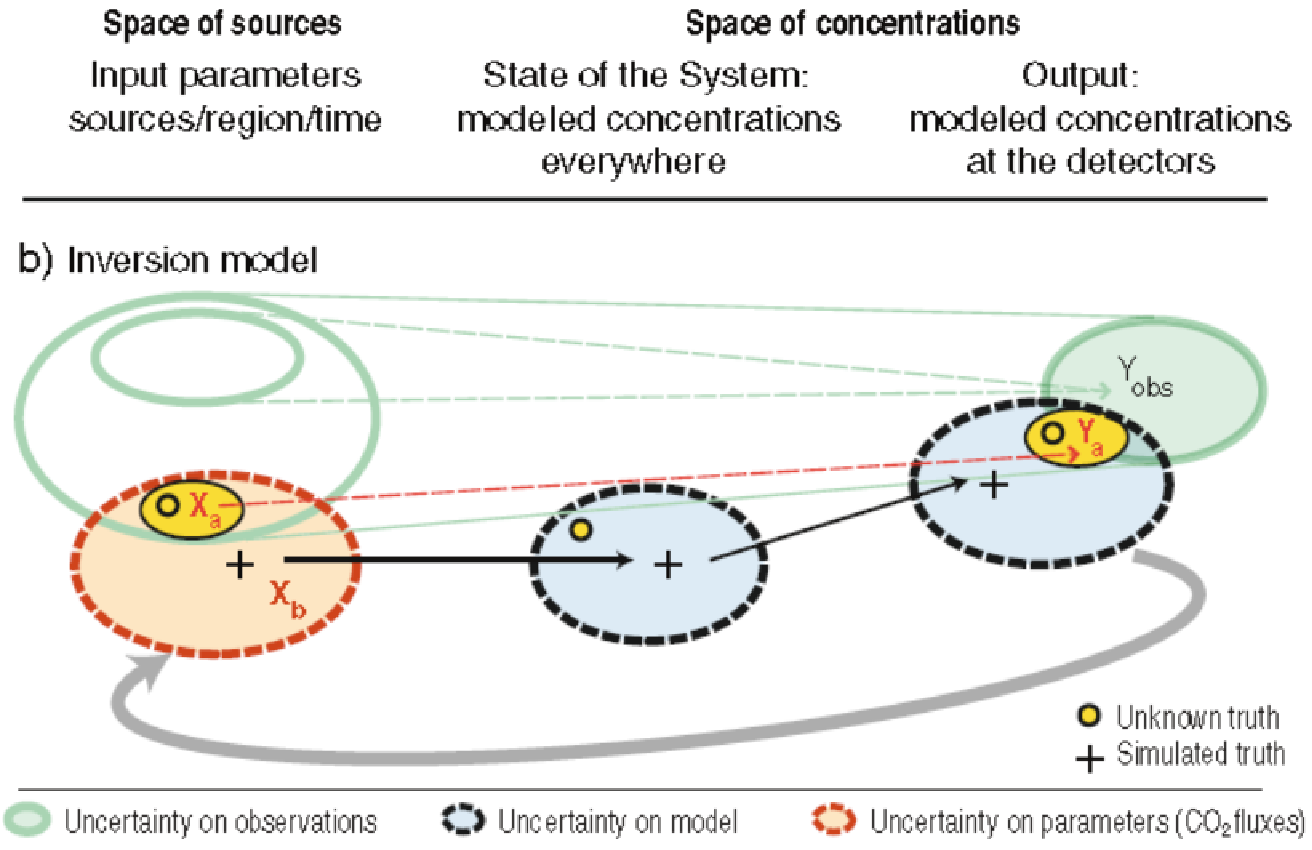
New version
EDGAR v50

Natural sources

…

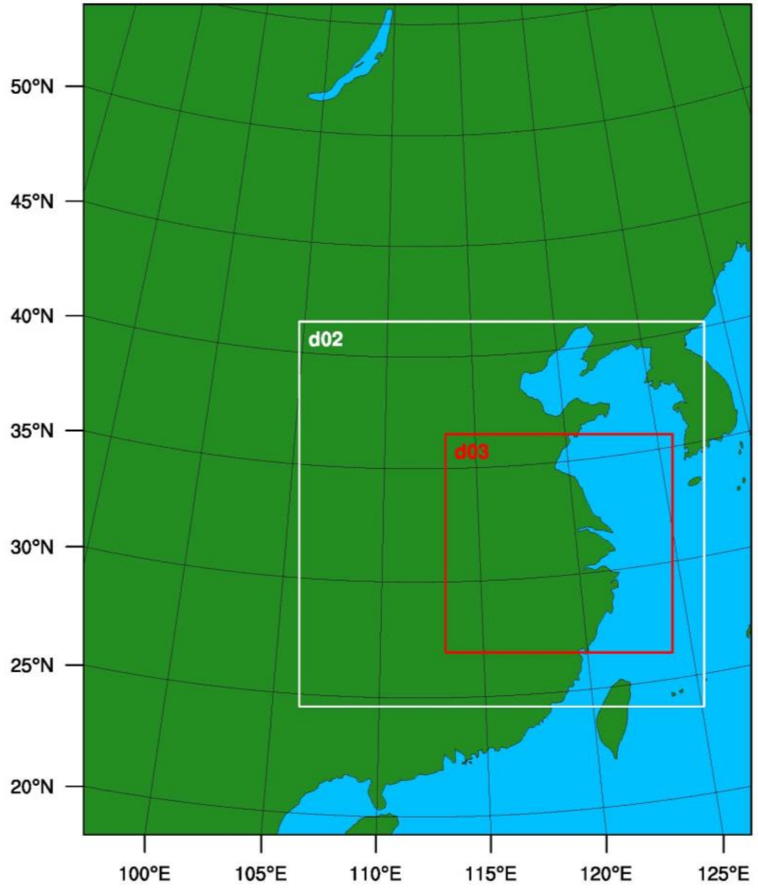



30 m × 30 m
↓
0.1° × 0.1°




(Ciais et al., 2010)

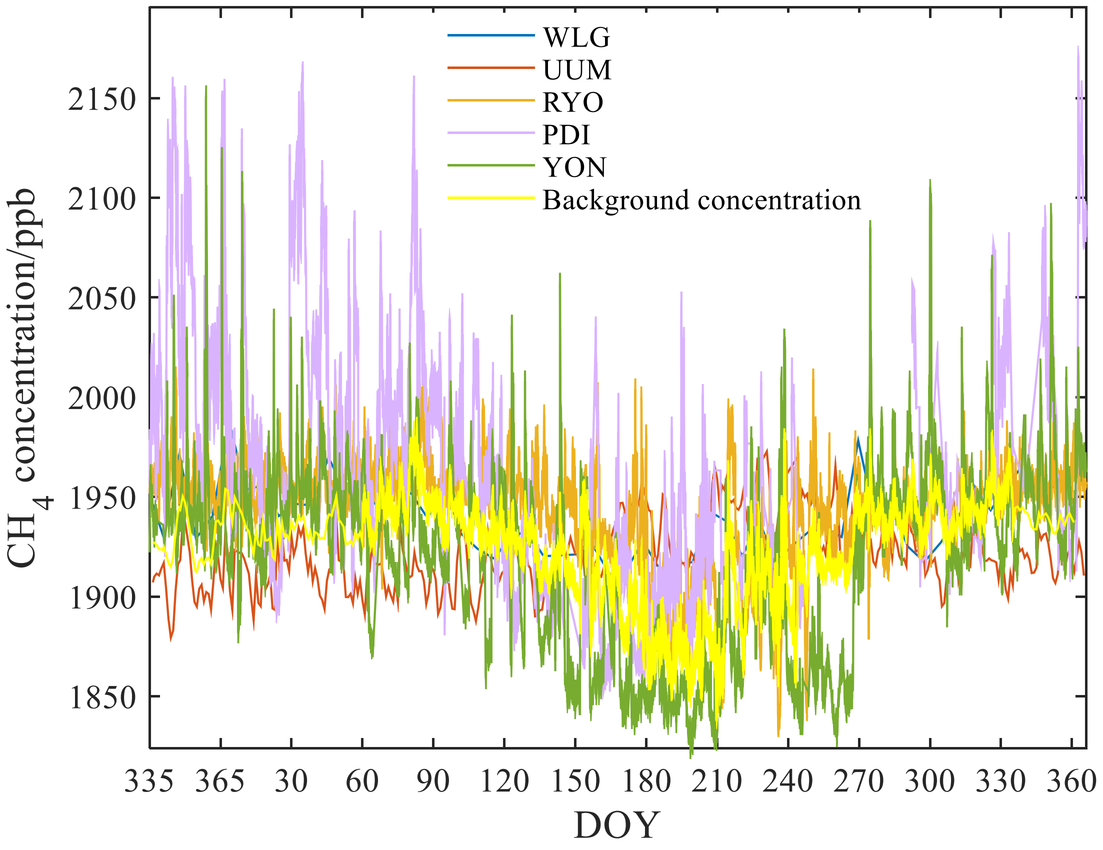
WRF-STILT model
https://uataq.github.io/stilt/img/animation-example.webm




- $X_a$: posteriori emissions
- $X_b$: priori emissions
- $Y_a$: optimized concentration
- $Y_{obs}$: observed concentration
- ○ : true values (assumed)
- \+ : simulated values

The spatial resolutions for d01, d02 and d03 are 27 km, 9 km and 3 km.

## A scale factor Bayesian inverse (SFBI) method




Purposes

$Y_a \approx Y_{obs}$

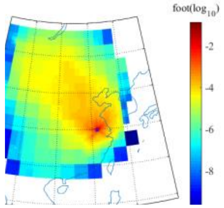
Posteriori scaling factors (?) ≈ A priori scaling factors ( default value is 1)

# 3

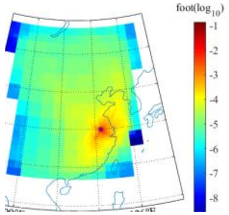
## Results & discussion

# 3 Results & discussion

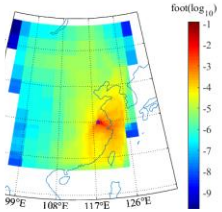
(a)



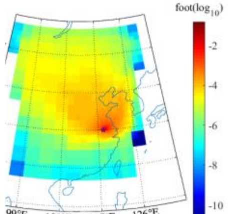

(b)



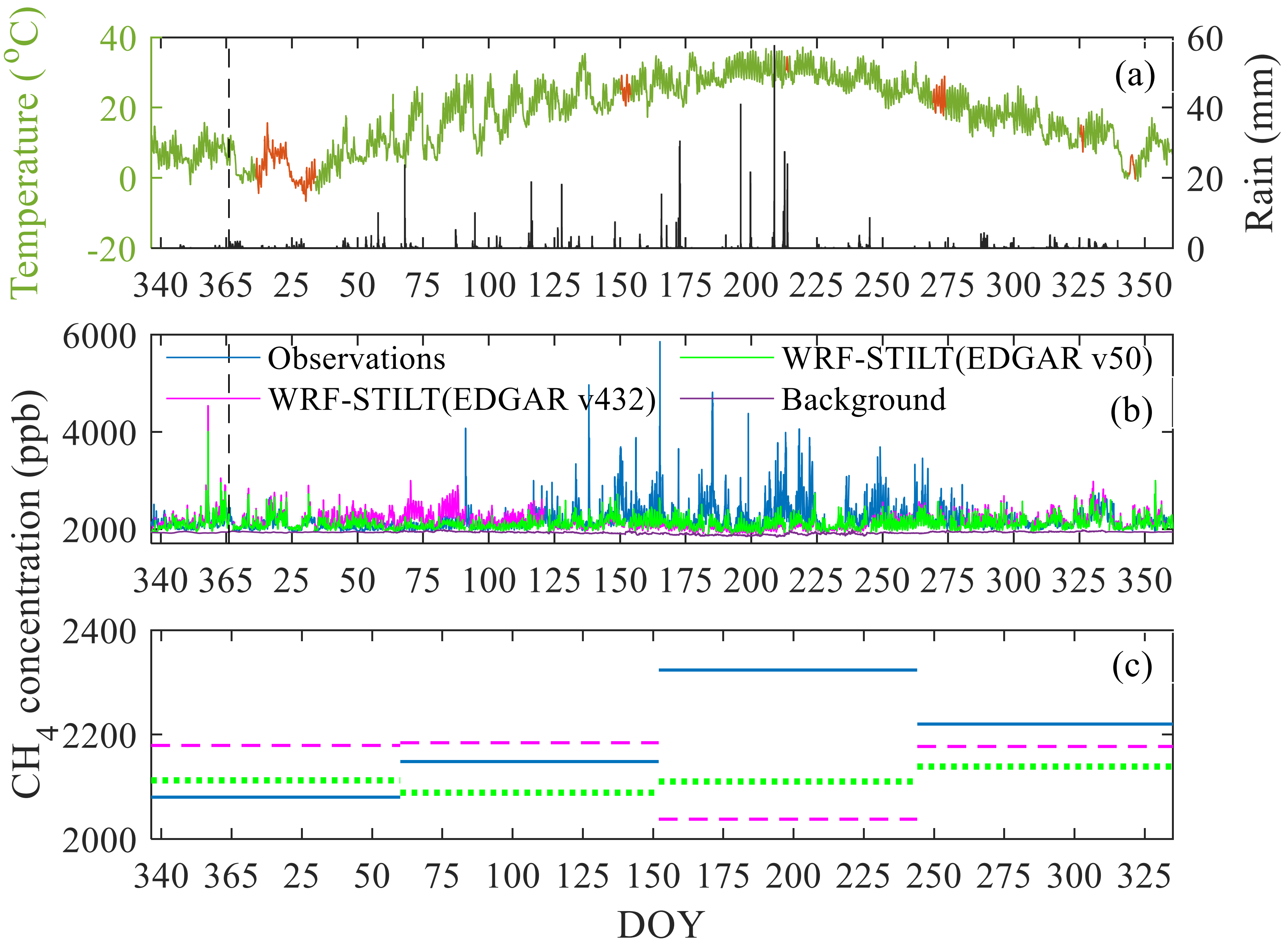

(c)




(d)

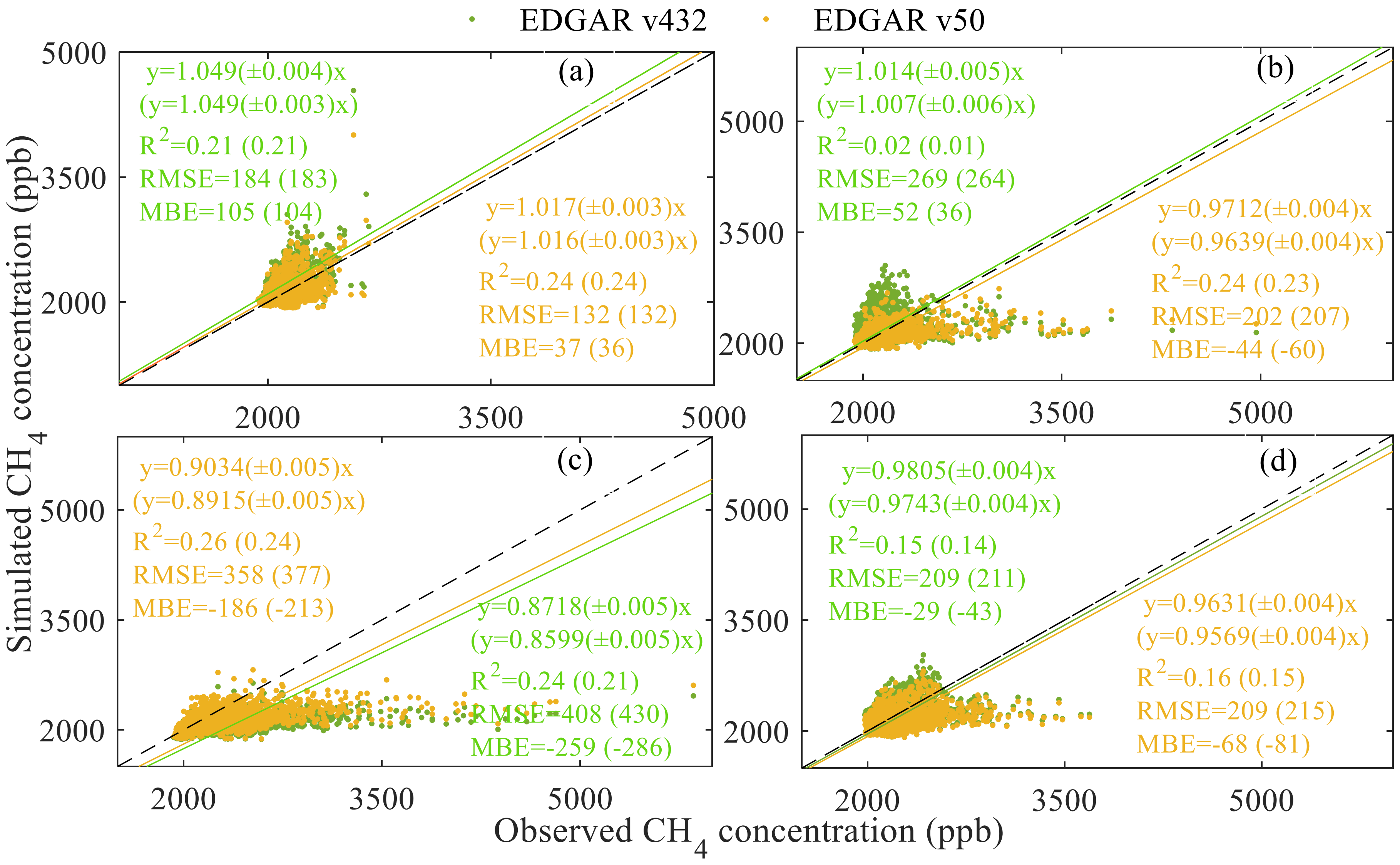



(a) Winter
(b) Spring
(c) Summer
(d) Autumn



Temperature (°C)
Rain (mm)
(a)
(b)
(c)
Observations
WRF-STILT(EDGAR v50)
WRF-STILT(EDGAR v432)
Background
CH4 concentration (ppb)
DOY
340 365 25 50 75 100 125 150 175 200 225 250 275 300 325 350

Including emissions from wetlands

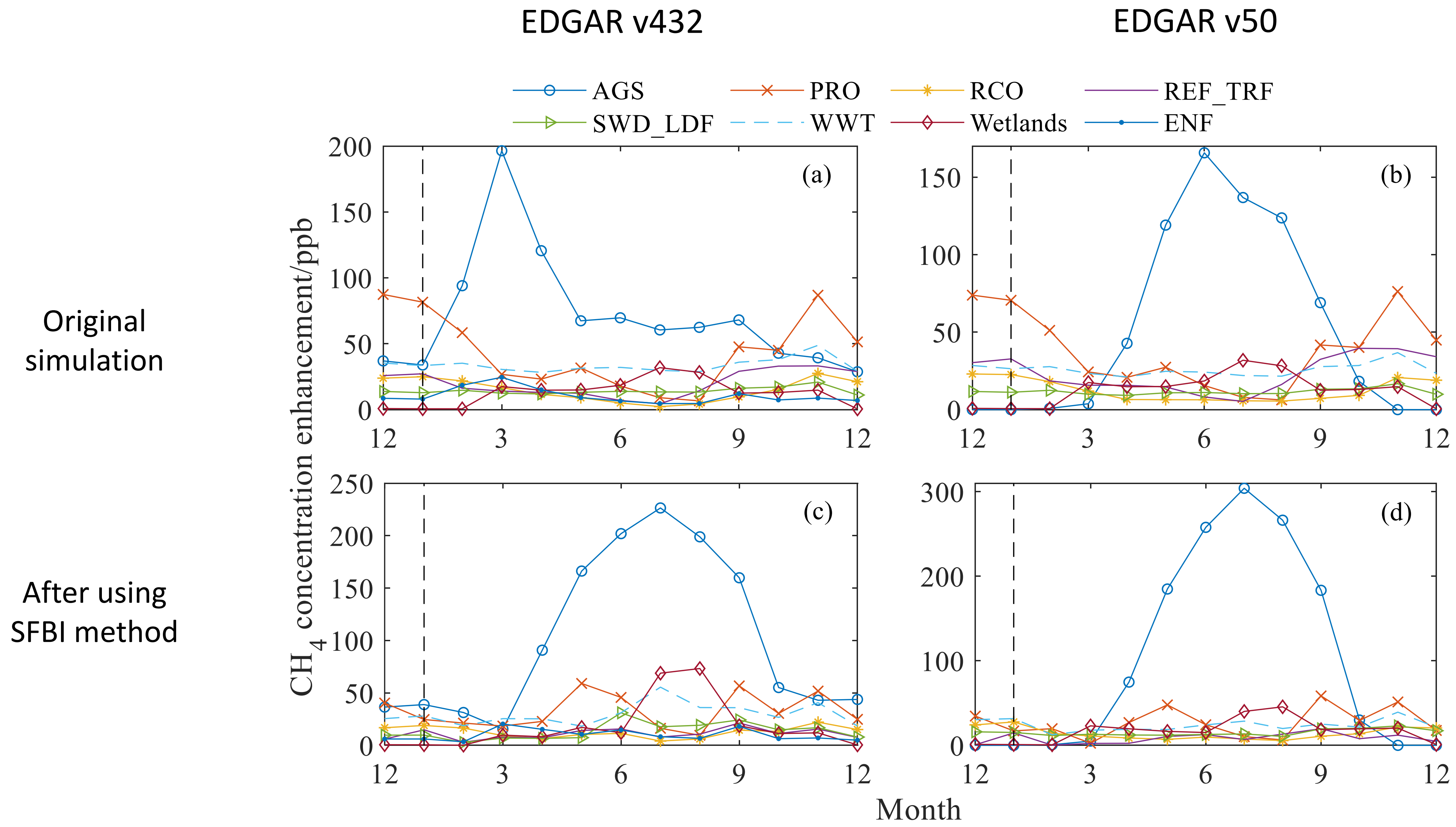



(a) Winter
(b) Spring
(c) Summer
(d) Autumn

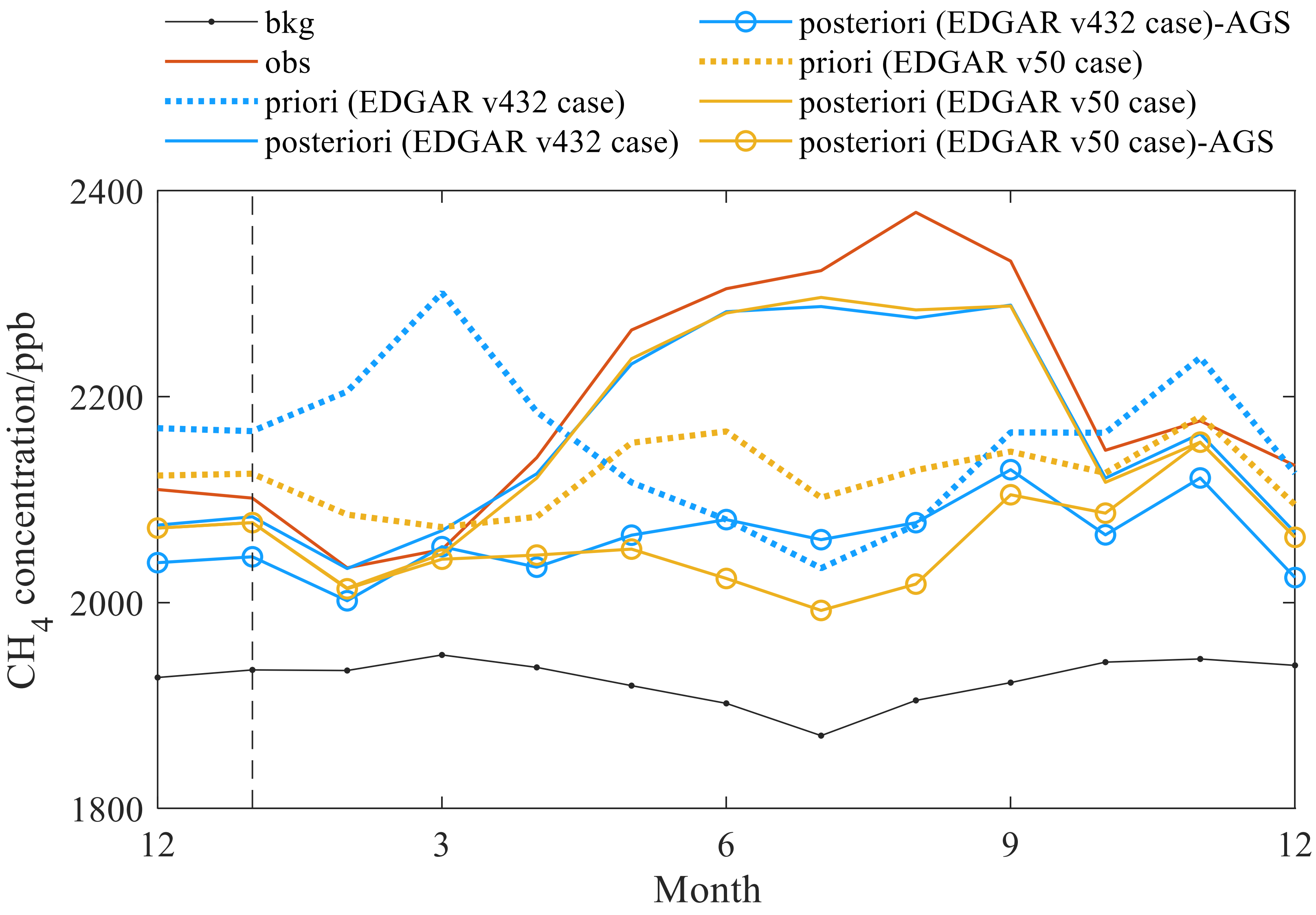
Scaling factors for the main methane sources on a monthly time scale based on EDGAR v50

| Time | AGS | PRO | RCO | REF_TRF | SWD_LDF | WWT | Wetlands | Other |
|---|---|---|---|---|---|---|---|---|
| Dec 2017 | 1.36 | 0.47 | 1.05 | 0.02 | 1.36 | 1.07 | 1.36 | 1.36 |
| Jan 2018 | 1.36 | 0.24 | 1.22 | 0.45 | 1.36 | 1.20 | 1.36 | 1.36 |
| Feb 2018 | 0.93 | 0.39 | 0.78 | 0.01 | 0.93 | 0.45 | 0.93 | 0.93 |
| Mar 2018 | 1.32 | 0.10 | 0.93 | 0.14 | 1.32 | 0.77 | 1.32 | 1.32 |
| Apr 2018 | 1.75 | 1.29 | 1.33 | 0.15 | 1.33 | 0.90 | 1.33 | 1.33 |
| May 2018 | 1.55 | 1.75 | 1.11 | 0.72 | 1.11 | 0.76 | 1.11 | 1.11 |
| Jun 2018 | 1.56 | 1.57 | 1.54 | 1.54 | 1.54 | 1.00 | 0.82 | 1.54 |
| Jul 2018 | 2.22 | 1.31 | 1.31 | 1.31 | 1.16 | 1.30 | 1.26 | 1.31 |
| Aug 2018 | 2.15 | 1.01 | 1.01 | 0.82 | 1.01 | 0.92 | 1.61 | 1.01 |
| Sept 2018 | 2.66 | 1.40 | 1.48 | 0.61 | 1.48 | 0.90 | 1.48 | 1.48 |
| Oct 2018 | 1.64 | 0.73 | 1.50 | 0.20 | 1.50 | 0.76 | 1.50 | 1.50 |
| Nov 2018 | 1.38 | 0.67 | 1.05 | 0.31 | 1.38 | 1.07 | 1.38 | 1.38 |
| Dec 2018 | 1.74 | 0.39 | 1.08 | 0.14 | 1.74 | 0.90 | 1.74 | 1.74 |

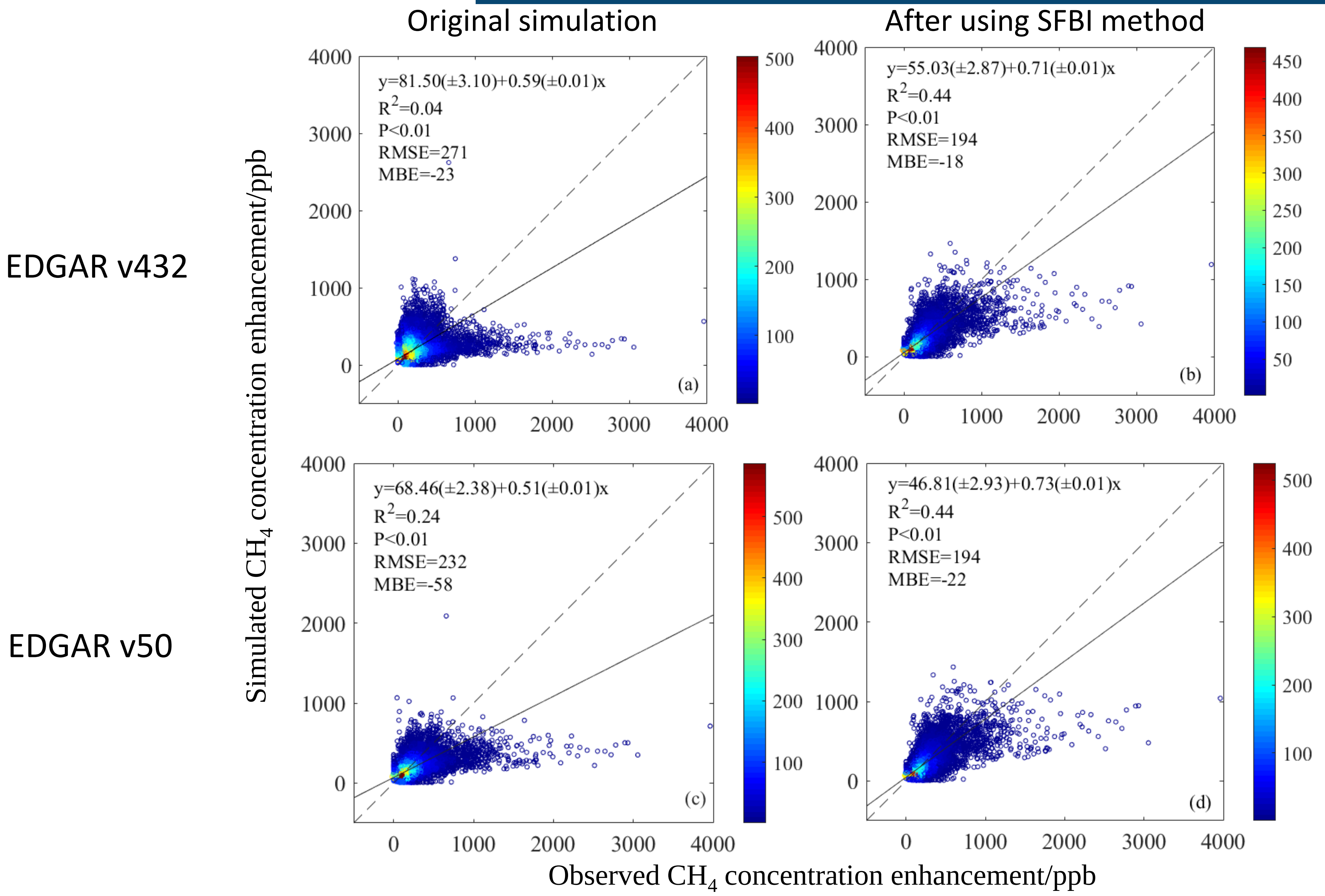
AGS = Agricultural soil; PRO = fuel exploitation; RCO = Energy for building; REF_TRF = Oil refineries and Transformation industry; SWD_LDF = Solid waste landfills; WWT = Waste water handling; Wetlands = wetlands (Marshland and mudflats) and water bodies (rivers, lakes, ponds and reservoirs); Other = the sum of remaining categories (depending on the month). The space filled with gray indicates that the emission source was classified as other in a specific month.



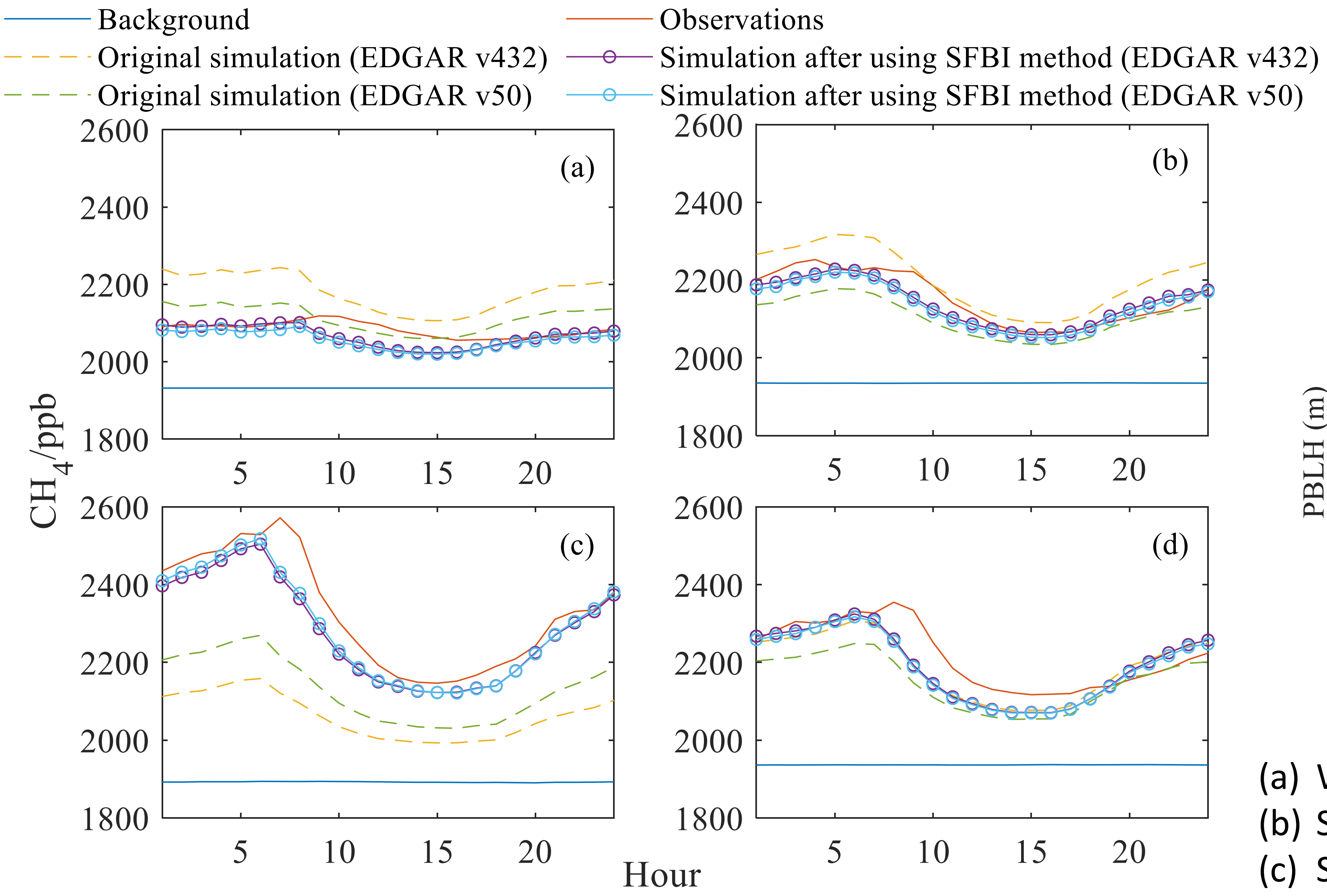
EDGAR v432
EDGAR v50
Original simulation
After using SFBI method
AGS
PRO
RCO
REF_TRF
SWD_LDF
WWT
Wetlands
ENF
(a)
(b)
(c)
(d)
CH4 concentration enhancement/ppb
Month

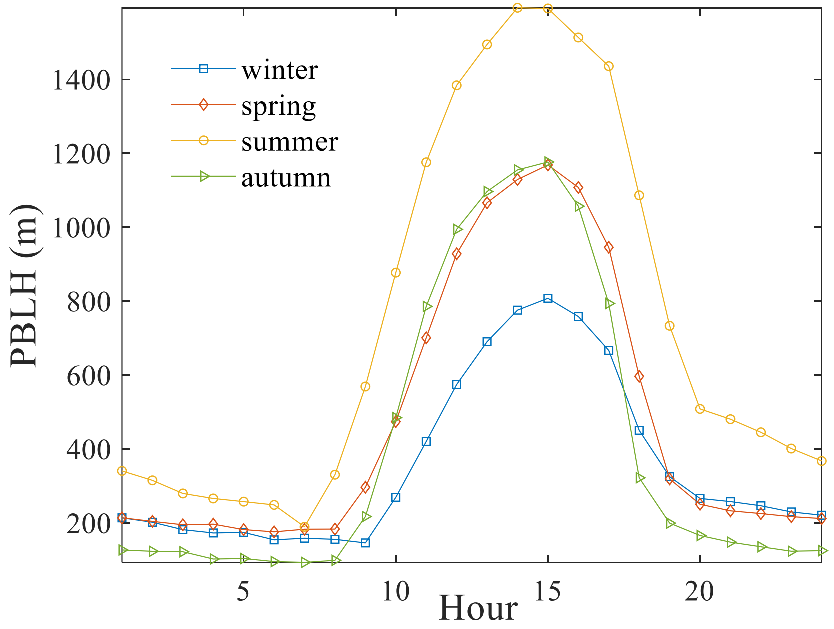

bkg
obs
priori (EDGAR v432 case)
posteriori (EDGAR v432 case)
posteriori (EDGAR v432 case)-AGS
priori (EDGAR v50 case)
posteriori (EDGAR v50 case)
posteriori (EDGAR v50 case)-AGS
2400
2200
2000
1800
CH4 concentration/ppb
12
3
6
9
12
Month

# 3 Results & discussion



# 3 Results & discussion

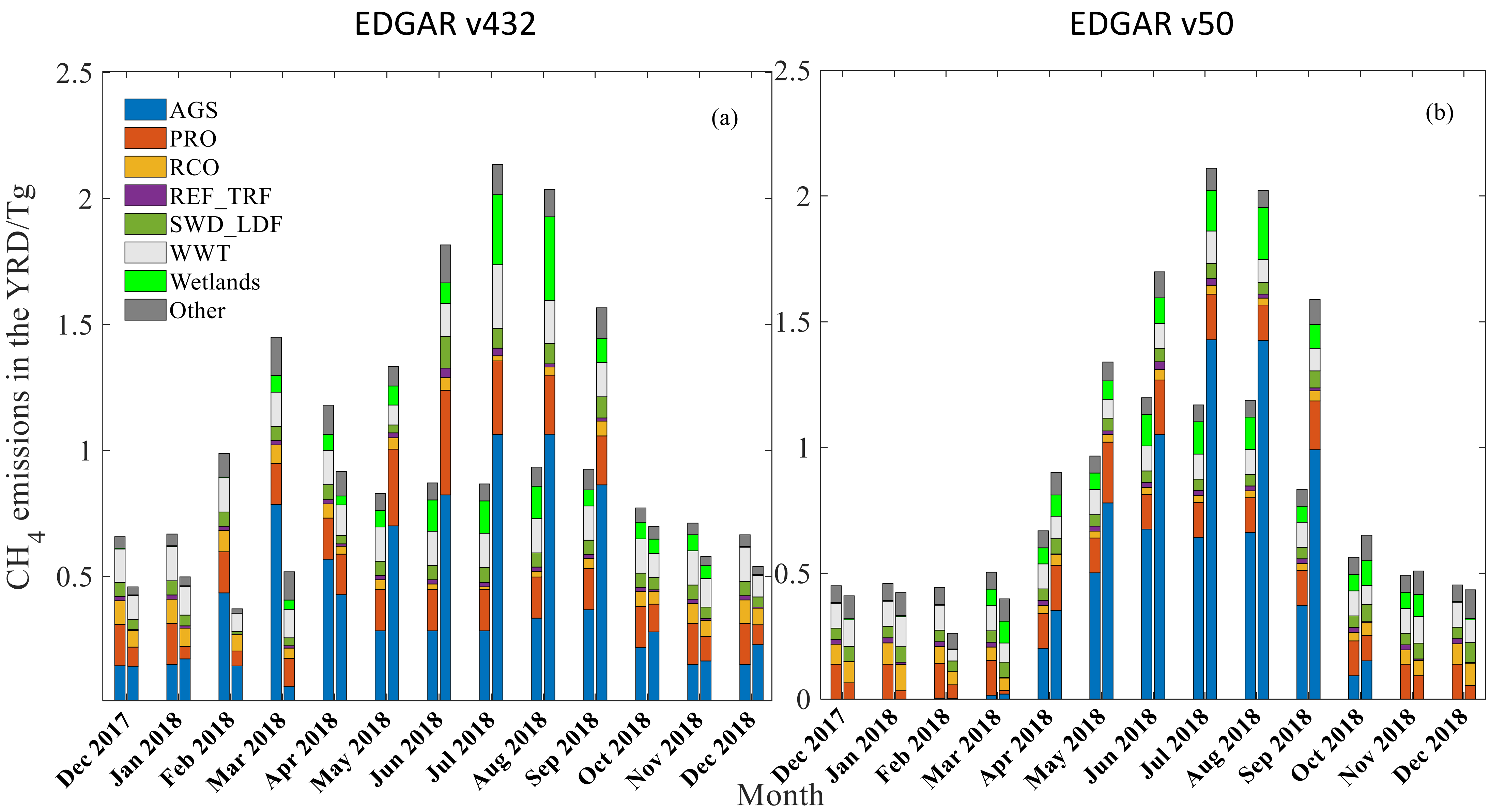



(a) Winter
(b) Spring
(c) Summer
(d) Autumn

| Date | EDGAR v50 | AGS | PRO | RCO | REF_ TRF | SWD_ LDF | WWT | Wetlands | Other | All |
|---|---|---|---|---|---|---|---|---|---|---|
| Dec 2017 | *a priori* | 0.00 | 8.96 | 5.18 | 1.26 | 2.87 | 6.40 | 0.21 | 4.32 | 29.20 |
| | *posteriori* | 0.00 | 4.20 | 5.45 | 0.03 | 3.91 | 6.83 | 0.29 | 5.89 | 26.60 |
| Jan 2018 | *a priori* | 0.00 | 8.97 | 5.50 | 1.32 | 2.96 | 6.45 | 0.21 | 4.35 | 29.76 |
| | *posteriori* | 0.00 | 2.17 | 6.72 | 0.60 | 4.02 | 7.72 | 0.29 | 5.91 | 27.42 |
| Feb 2018 | *a priori* | 0.26 | 9.93 | 4.77 | 1.40 | 3.27 | 7.14 | 0.21 | 4.79 | 31.78 |
| | *posteriori* | 0.24 | 3.83 | 3.72 | 0.01 | 3.06 | 3.22 | 0.20 | 4.47 | 18.77 |
| Mar 2018 | *a priori* | 0.99 | 8.97 | 3.45 | 1.24 | 2.96 | 6.45 | 4.27 | 4.36 | 32.69 |
| | *posteriori* | 1.30 | 0.93 | 3.20 | 0.18 | 3.90 | 4.94 | 5.63 | 5.75 | 25.83 |
| Apr 2018 | *a priori* | 13.50 | 9.27 | 2.14 | 1.37 | 3.06 | 6.66 | 4.27 | 4.53 | 44.79 |
| | *posteriori* | 23.61 | 12.00 | 2.83 | 0.21 | 4.05 | 5.97 | 5.66 | 6.01 | 60.35 |
| May 2018 | *a priori* | 32.53 | 8.97 | 1.76 | 1.30 | 2.96 | 6.45 | 4.27 | 4.37 | 62.61 |
| | *posteriori* | 50.53 | 15.67 | 1.95 | 0.94 | 3.28 | 4.88 | 4.74 | 4.85 | 86.83 |
| Jun 2018 | *a priori* | 45.25 | 9.27 | 1.82 | 1.34 | 3.06 | 6.66 | 8.33 | 4.50 | 80.23 |
| | *posteriori* | 70.43 | 14.52 | 2.80 | 2.06 | 3.56 | 6.64 | 6.81 | 6.92 | 113.74 |
| Jul 2018 | *a priori* | 41.66 | 8.97 | 1.76 | 1.31 | 2.96 | 6.45 | 8.33 | 4.34 | 75.78 |
| | *posteriori* | 92.58 | 11.73 | 2.31 | 1.72 | 3.87 | 8.39 | 10.49 | 5.67 | 136.75 |
| Aug 2018 | *a priori* | 42.92 | 8.97 | 1.76 | 1.25 | 2.96 | 6.45 | 8.33 | 4.33 | 76.97 |
| | *posteriori* | 92.41 | 9.10 | 1.79 | 1.02 | 3.00 | 5.93 | 13.41 | 4.40 | 131.07 |
| Sept 2018 | *a priori* | 24.98 | 9.27 | 1.82 | 1.28 | 3.06 | 6.66 | 4.27 | 4.50 | 55.84 |
| | *posteriori* | 66.38 | 12.99 | 2.70 | 0.78 | 4.53 | 6.03 | 6.33 | 6.67 | 106.40 |
| Oct 2018 | *a priori* | 6.02 | 8.97 | 2.16 | 1.32 | 2.96 | 6.45 | 4.27 | 4.39 | 36.53 |
| | *posteriori* | 9.85 | 6.57 | 3.24 | 0.26 | 4.43 | 4.90 | 6.40 | 6.57 | 42.23 |
| Nov 2018 | *a priori* | 0.00 | 9.27 | 3.83 | 1.35 | 3.06 | 6.66 | 4.27 | 4.53 | 32.96 |
| | *posteriori* | 0.00 | 6.24 | 4.02 | 0.41 | 4.21 | 7.11 | 5.88 | 6.23 | 34.10 |
| Dec 2018 | *a priori* | 0.00 | 8.97 | 5.27 | 1.31 | 2.96 | 6.45 | 0.21 | 4.24 | 29.40 |
| | *posteriori* | 0.00 | 3.52 | 5.70 | 0.18 | 5.16 | 5.83 | 0.37 | 7.39 | 28.15 |

unit: nmol/$m^2$/s (EDGARv50).



EDGAR v432
EDGAR v50
(a)
(b)
AGS
PRO
RCO
REF_TRF
SWD_LDF
WWT
Wetlands
Other
CH4 emissions in the YRD/Tg
Month
0
0.5
1
1.5
2
2.5
Dec 2017
Jan 2018
Feb 2018
Mar 2018
Apr 2018
May 2018
Jun 2018
Jul 2018
Aug 2018
Sep 2018
Oct 2018
Nov 2018
Dec 2018

$CH_4$ emissions in the YRD in 2018

| | | Emissions from agricultural soils (Tg) | Anthropogenic emissions (Tg) | Emissions from wetlands (Tg) | Total (Tg) |
|---|---|---|---|---|---|
| EDGAR v432 | *a priori* | 4.01±2.98 | 10.08±3.51 | 0.78±0.62 | 10.87±3.56 |
| | *posteriori* | 6.00±2.99 | 11.97±3.39 | 1.05±0.91 | 13.01±3.51 |
| EDGAR v50 | *a priori* | 3.17±2.99 | 8.16±3.36 | 0.78±0.62 | 8.94±3.41 |
| | *posteriori* | 6.21±2.61 | 11.34±2.92 | 1.01±0.70 | 12.35±3.00 |

Agricultural statistics show that 90% of the rice grown in the YRD is medium and late-season rice (China Statistics Bureau, 2019) and the length of growing season was assumed to be 120 d ($17^{th}$ Jun- $14^{th}$ Oct).

Emissions during the growing season accounted for about 58.4% for EDGAR v432 and 71.0% for EDGAR v50 of the *posteriori* $CH_4$ emissions from AGS, respectively.

# 4

# Conclusions

# 4 Conclusions

- The main factor causing seasonal changes in atmospheric $CH_4$ concentration in the YRD was rice cultivation.
- The *posteriori* anthropogenic emissions were 11.97 Tg and 11.33 Tg using EDGAR v432 and EDGAR v50 and the proportion of AGS ranged from 50.1% to 54.8% respectively. The *posteriori* emissions from natural sources (including wetlands and water bodies) were 1.05 Tg and 1.01 Tg in YRD in 2018.
- The underestimation of the anthropogenic $CH_4$ emissions in the YRD from the inventory products was mainly due to the underestimation of emissions from AGS, especially in growing seasons. If this emission source was not considered, the deviation between the estimated value of other anthropogenic emission sources and the *posteriori* results was small (0.10 Tg in EDGAR v432 and 0.14 Tg in EDGAR v50).

# T h a n k s